Development of an innovative early warning system to manage bathing conditions in the Seine River in Paris region

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KEYWORDS

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ABBREVIATIONS

DWC: Digital Water City

EWS: Early Warning System

FIB: Fecal Indicator Bacteria

KWB: Kompetenzzentrum Wasser Berlin

SIAAP: Syndicat Interdépartemental pour l'Assainissement de l'Agglomération Parisienne

WWTP: Wastewater Treatment Plant

ABSTRACT

Swimming is a recreational activity that takes place in natural surface waters. These waters are therefore susceptible to be contaminated by short-term pollution and so become dangerous for bathers. The current bathing water directive (2006/7/EC) demands, for such bathing sites, an efficient surveillance with monitoring and an early warning system. The aim is to prevent bathers from being exposed to pollution. The first water directives in France set out the legal thresholds that must not be surpassed, using faecal bacteria as an indicator of water pollution. *E. coli* are chosen as indicators of recent faecal pollution and intestinal enterococci are used to highlight older pollution. The present study proposes the future development of an Early Warning System in Paris for bathing and for the aquatic activities of the Olympic Games in 2024.

1 INTRODUCTION

The project called “Digital Water City”, funded by the European program for innovation H2020, under the lead of Kompetenzzentrum Wasser Berlin (KWB) is aiming at developing digital solutions for the management of sanitation and water uses in five European Cities. Among these solutions, the public utility for sewage transport and treatment of the 9 million inhabitants of the greater Parisian region, the SIAAP, is leading a project for the development and implementation of an Early Warning System (EWS) that will provide a forecast of the water quality of the Seine and Marne Rivers for bathing uses both for the 2024 Olympic and Paralympic Games and the bathing sites in legacy of the Games.

The development of this EWS relies on two complementary modeling approaches. One is using combination of deterministic models of the sanitation system (pollutographs generation) with the bacterial behavior in the Seine River and its main tributary the Marne River. The behavior of the different FIB populations in the river will be forecasted using the ProSe phenomenological model developed in the frame of the PIREN Seine research program (Even and al., 1998). The second approach will be based on the use of a statistical modelling methodology (Seis and al., 2018) of bathing water quality developed by KWB. It aims at forecasting bacterial concentration in the bathing sites using a set of influential factors such as climate (Panidhapu and al., 2020) and rain characteristics as well as river and WWTP flowrates. The first approach with deterministic models will also provide additional data sets sets to supplement the available measurements made in the river for construction of the second approach. Both approaches are complementary in order to: 1) study forecasts uncertainties and 2) update the statistical model. Finally, based on the obtained results, a near real time prediction of *E.coli* in water will be developed.

In addition to these numerical tools, there is a need on having rapid quantification methods of *E. coli* and fecal enterococci with smart sensors. Fluidion is the industrial partner of the DWC project and develops an *in situ* FIB sensor called ALERT System (Angelescu et al., 2018). This sensor can analyse seven samples before requiring a routine maintenance to recharge the consumables, allowing the monitoring of a pollution event. The system will therefore permit the collection of FIB data in the Seine and Marne rivers to compare with the simulations done with the determinist model ProSe.

In the end, the project will provide an application for mobile phones to inform on daily basis the larger public about the bathing status of the swimming locations. The project will also involve sociologists (INRAE) who will explore public expectations in relation to bathing water quality information and how an EWS changes the governance of water quality.

2 METHODS

PLANNED ACTIONS AT SIAAP TO REALIZE THE EWS

ProSe modeling

The ProSe model simulates the evolution of water quality along the Seine and Marne rivers. The river state at each simulated point is defined by physical variables (like water speed, water level…) and biochemical variables that may depend on reactions with other factors like temperature. Different modules are present in the model to simulate these variables such as the hydraulic module or the module describing the FIB (Fecal Indicator Bacteria) dynamics (Servais et al., 2010). The model makes it possible to link the river's metabolism with the anthropogenic pressure due to urban discharges. Figure 1 presents a flowchart of how ProSe works.

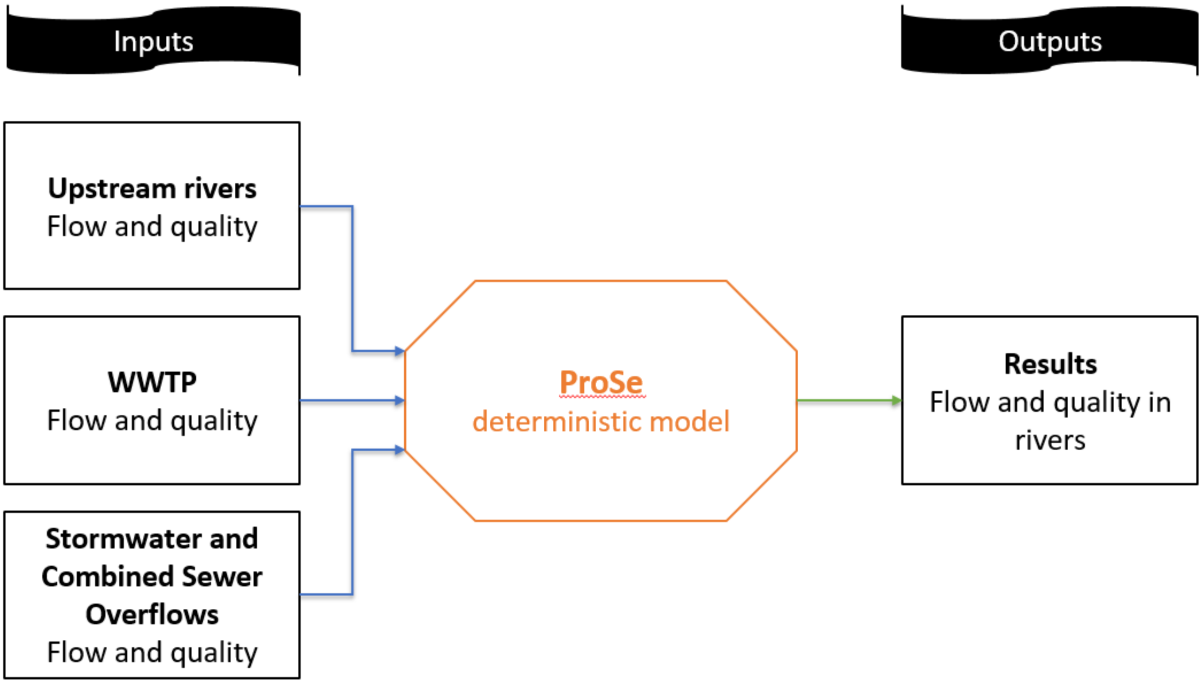

Figure 1: Description of the ProSe model

ProSe requires input data to start a simulation. These inputs are flowrates and quality at the different river inputs considered in the model. The main input is the upstream rivers at the beginning of the perimeter considered in ProSe. The current simulations done at SIAAP consider a perimeter around Paris with an initialization in Ablon for the Seine river and Noisiel for the Marne river and with the end of the simulation at the Suresnes dam, downstream of Paris. It is also planned to move the initialisation sites farther upstream during this project. Then there are the discharges in the rivers with on one side the wastewater treatment plants (WWTP) and on the other side the stormwater overflows that mainly occur during rainy weather. Finally, the simulation starts and the model solves the different equations of each module with the input data to determine the flow and quality all along the selected river section.

Actions planned for the EWS

The first simulations of the module describing the dynamics of BIF show a good adequacy between the measured BIF and those simulated during the summer of 2010 with, however, some notable differences in wet weather (Poulin and al., 2013). But nowadays they are more collected data used as input for the simulations and also more FIB measurements done in the Seine and Marne rivers in view of future bathing sites. These data will be used for more accurate simulations of FIB in rivers and the possibility for comparison between simulated variables and measured concentrations. In order to develop the EWS, some actions are required to improve FIB simulations. First, an improvement of the estimation of inputs, in particular for FIB concentrations in stormwater and combined sewer overflows. Then, the development of high-frequency simulations that will give a better representation of short-term pollution events. Finally, the improvement of the modelled phenomena will be studied by refining the determination of the variables used for the growth and mortality of FIB in the ProSe model and their distribution in the different layers of the river (water, total suspended solids and sediment).

The main objective at SIAAP is the improvement of FIB simulations with ProSe. On the one hand, this will allow simulations in near-real time by working on the on-line integration of data measured in real time or slightly delayed in Prose simulations. On the other hand, the improved simulations will allow the creation of data series that will be used to calibrate the statistical model developed by KWB.

The use of ProSe also allows to modify the study area according to future changes. Indeed, networks and structures may evolve in the future. ProSe therefore allows to work on the foreseeable evolution of discharges in the near future (new equipment, new inputs, climate/weather) and thus to build an EWS that adapts to a changing situation. The creation of data sets with potential future changes will be used to test the evolution of the statistical model and to estimate the necessity to recalibrate it.

FIB INPUTS IN SEINE AND MARNE RIVERS

Data collection

It is necessary to have a complete set of data for simulations with ProSe. The study period for the development of the EWS covers 4 years from 2016 to 2019. As shown in Figure 1, the mandatory data are flowrates and quality in WWTP and stormwater overflows. These data are collected at high frequency (5 minutes time step) when available. Other data of interest are rain gauges as well as river quality and microbiology analyses to compare simulation with measured data at some key locations in the river. In addition, Fluidion realizes measurement campaigns with their ALERT system to provide FIB data in strategic sites like at the Alma Bridge. . On a wider scale, the routinely measured FIB concentration data from grab samples at several locations in the Ile-de-France region was collected from various partners involved in the water sector. This data collection will also serve as the foundation for the statistical model developed by KWB.

Measurement campaigns

In order to complete the data collection and to acquire knowledge in sites where there were no available data, measurement campaigns were conducted in 2019 and 2020 as presented in Figure 2.

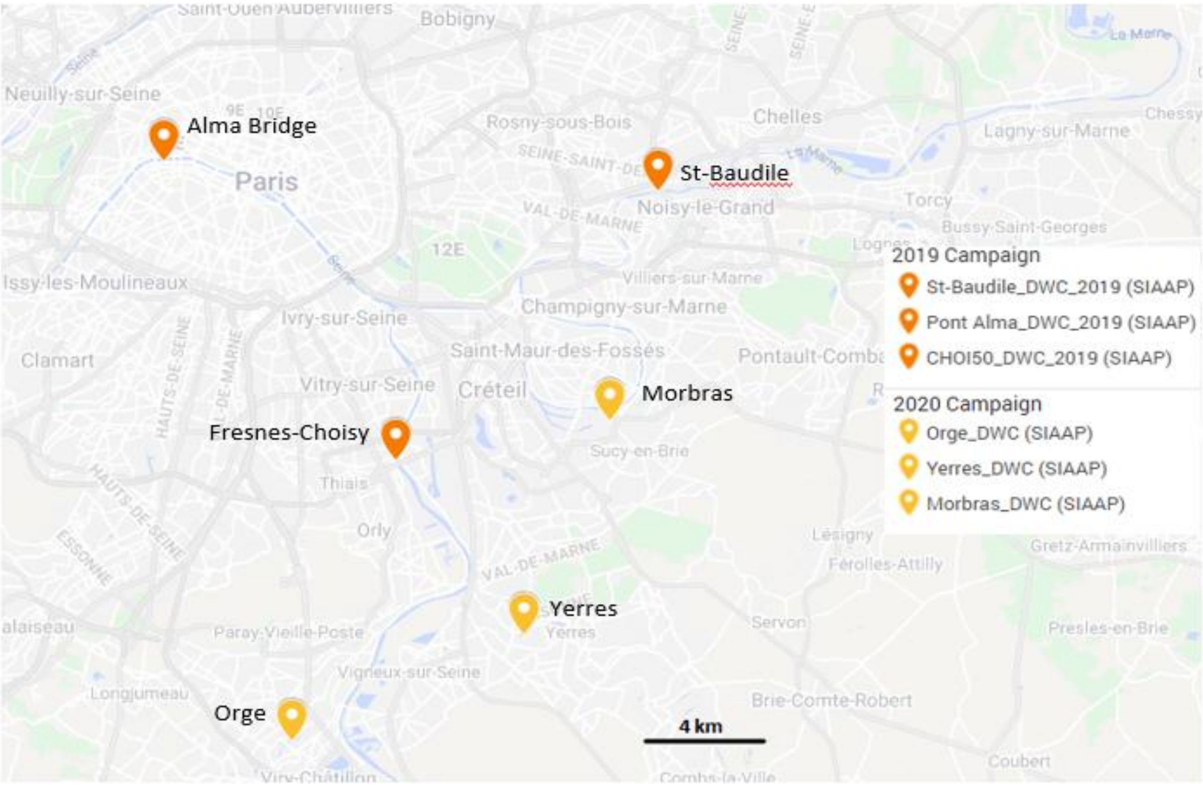

Figure 2: Map of 2019 and 2020 campaigns for DWC H2020 project

The 2019 campaign focused on the Seine and Marne rivers with low scale spatial variability (100 to 200 metres long for 12 spaced-apart samples) campaigns at the shores of the rivers and a microbiological monitoring at the Alma Bridge. This monitoring was carried out by laboratory analyses and by using the ALERT system of Fluidion. Moreover, two discharges points were monitored: the “Fresnes-Choisy” in Seine and the “Saint-Baudile” in Marne. The 2020 campaign focused on smaller rivers that are tributaries of the Seine and Marne. “Yerres” and “Orge” were monitored for the Seine’s tributaries and the “Morbras” was monitored for the Marne’s tributary. The objective is to better determine the FIB contributions of upstream tributaries during dry weather and rainy weather.

3 RESULTS

CURRENT DEVELOPMENT OF FIB MODELING IN PROSE

The first action is to determine the optimal time-step for inputs data of the model. Indeed, for a lack of higher frequency measurements available, the past and current simulations using the FIB module of ProSe are done with a 24h average value for input data of discharges. Such a low frequency of input data is not representative of the reality of the discharges events. It results in an overly smoothed discharge profile, which often does not allow to properly compare simulation results with the grab sample measurements available. Therefore, it is necessary to define what is the optimal time-step and the differences between different simulations when the time-step fluctuates using the high frequency data collected. Once the results have been analyzed and the influence of the time-step on the simulations is known, a value will be selected and used for future simulations.

Then, the next step is to start base simulations for the study period of 2016 to 2019 with the data collected as inputs at the time-step selected. These simulations will serve as a base for comparison with FIB measured data and with future simulations. Indeed, a study will be done on the comparison between simulations with flows measured data as inputs versus simulations with simulated flows data as inputs. The flows in discharges and networks are simulated by MAGES, a software used at SIAAP for active management of the sewer network facilities.

Conclusions

The development of the Early Warning System will be based on two approaches, a statistical one and a determinist one with ProSe simulation. They are still interconnections between these approaches since the statistical model will use simulated data from ProSe for calibration and to evaluate the necessity of recalibration as the network evolves.

It is clear that the development of the EWS requires a lot of data to predict FIB quality at bathing sites. Moreover, to predict in near real time, the data will have to be gathered online. This is why it will be important in the future step to assess the key data to collect.

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